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Study on the Effect of Rehabilitation Ball on the Microcirculation of the Affected Limb after Transradial Coronary Angiography in Patients with Coronary Heart Disease

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Abstract

Objective: To investigate the effect of a rehabilitation ball on the microcirculation of the affected limb after transradial coronary angiography in patients with coronary heart disease. **Methods:** Thirty-four patients undergoing transradial coronary intervention were selected as study subjects. They were randomly divided into a study group and a control group on the day after coronary intervention using random data selection. Blood flow velocity before coronary intervention, return to the ward after coronary intervention, and at 2, 4, 6, and 8 hours after coronary intervention, as well as changes in blood flow after releasing the pressure device, were compared. Observations included changes in limb swelling before and after coronary intervention, pain levels, anxiety scores, and quality of sleep scores. **Results:** The study group showed significant improvements in swelling, pain, and sleep quality compared to the control group, with statistically significant differences ($P < 0.05$). However, there were no statistically significant differences in blood flow velocity changes and anxiety scores between the study and control groups ($P > 0.05$). **Conclusion:** Using a rehabilitation ball for wrist exercises in patients undergoing transradial coronary intervention does not significantly affect the peripheral circulation on the side of the coronary intervention but effectively improves limb swelling, reduces pain levels, and promotes patient recovery.

Keywords

Coronary Intervention, Blood Flow Velocity, Limb Swelling, Care

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1. Introduction

Coronary heart disease, also known as coronary artery atherosclerotic heart disease, is primarily caused by narrowing or spasm of the coronary arteries leading to ischemia, hypoxia, or even necrosis. Clinically, it manifests as chest pain, difficulty breathing, and cold sweats, and severe cases can lead to shock. The disease predominantly affects middle-aged and elderly populations. With improvements in living standards and an aging population, the incidence of coronary heart disease is increasing annually. Currently, percutaneous coronary intervention (PCI) is widely used for the treatment of coronary heart disease, angina, myocardial infarction, and other related conditions [1]. It offers advantages such as minimal invasiveness and rapid efficacy, ensuring patient prognosis and timely hemostasis at the puncture site post-coronary intervention [2]. Although radial artery compression is the most widely used hemostatic technique, factors such as endothelial damage to the radial artery, local vascular narrowing, and immobilization under pressure post-coronary intervention often lead to symptoms such as hand swelling, pain, and numbness. Compression at the radial artery puncture site affects venous return in the distal limb, resulting in increased intravascular hydrostatic pressure and causing edema. Furthermore, pressure on the wrist joint and the resulting edema can further compress the median nerve and radial nerve, leading to pain and numbness in the palm and fingers. Impairment of venous return often resolves rapidly after the release of compression, but delayed recovery of microcirculation function (such as persistent endothelial damage) can lead to prolonged symptoms. Compared to isolated measurements of venous blood flow velocity or nerve conduction function, microcirculation parameters (capillary density, blood flow velocity, and tissue oxygen saturation) can more comprehensively reflect the state of tissue perfusion and have higher sensitivity to early damage. A typical manifestation is that the localized symptoms of nerve compression (such as numbness in the median nerve region) significantly overlap with areas of microcirculation abnormalities, which can be visually demonstrated using techniques like laser speckle imaging to show the relationship between ischemic areas and clinical symptoms. Taking wrist exercises as an example, their rehabilitation mechanism may cover three levels: ① enhancing the muscle pump effect to improve venous return and reduce capillary hydrostatic pressure; ② increasing blood flow shear force to repair endothelial function; ③ directly improving microcirculation perfusion to alleviate nerve ischemia. Monitoring venous return alone may overlook key microcirculation regulatory mechanisms such as endothelial repair. According to research by Huang Xuejia *et al.*, using grip balls for wrist exercises in patients after transradial coronary intervention can effectively reduce swelling in the affected limb, alleviate patient pain, and promote recovery [3].

2. Materials and Methods

2.1. General Information

In April 2024, 34 patients undergoing transradial coronary intervention in the cardiology department of the First Affiliated Hospital of Sun Yat-sen University were selected as research subjects.

Inclusion Criteria: 1) Age between 30 and 80 years, diagnosed with coronary heart disease via coronary angiography, with stable condition.

First-time undergoing coronary angiography. 2) Underwent PCI (percutaneous coronary intervention) or coronary angiography. 3) Normal upper limb muscle strength.

Exclusion Criteria: 1) Blood pressure >180/100 mmHg (1 mmHg = 0.133 kPa). 2) Upper limb hemiplegia or mental disorders. 3) Underwent femoral artery coronary angiography. 4) History of coagulation disorders. 5) Severe liver diseases.

There were no statistically significant differences in general information such as gender, age, educational level, and type of coronary intervention between the two groups of patients ($P > 0.05$), as shown in Table 1. This study was approved by the hospital's ethics committee, and all patients signed informed consent forms and voluntarily participated.

Table 1. Comparison of general information between the two groups of patients.

Group	Age (years)	Gender (cases)		Educational level (cases)		Type of coronary intervention (cases)	
		Male	Female	Middle school or below	High school or above	CAG	PCI
Study group (cases)	65.4 ± 9.8	12	5	8	9	9	8
Control group (cases)	59.4 ± 11.4	15	2	9	8	13	4
t-value	1.659	1.265		1.437		0.164	
p-value	0.107	0.215		0.160		0.871	

2.2. Methods

Both groups of patients used the Wo brand arterial compression hemostat provided by Hangzhou Shanyou Medical Equipment Co., Ltd. for radial artery puncture. After completing coronary angiography and returning to the ward, nursing staff should appropriately adjust the number of decompression turns based on the patient's puncture site swelling, bleeding, and limb sensation, with a recommended decompression of 1 - 1.5 turns every 2 hours. To avoid prolonged pressure leading to skin redness, pain, and swelling, the compression at the puncture site should be gradually loosened to its loosest state 6 - 8 hours after returning to the ward [4]. However, to prevent rebleeding, the hemostat should still be worn until the next morning before being removed.

In April, 34 patients undergoing coronary angiography or PCI in the cardiology department were randomly selected, using a simple random sampling method to select patients returning to the ward on the day of the procedure. They were divided into a study group and a control group, with 17 cases in each group.

Control Group: Patients were advised post-operatively to perform fist-clenching and relaxing exercises at a rate of 3 - 5 times per minute and instructed to avoid bending or exerting the wrist on the side of the procedure for 24 hours [5].

Study Group: The rehabilitation ball exercise model was used: the rehabilitation ball is placed in the palm and squeezed tightly, with the arm immobilized, using the pinky, ring finger, middle finger, and index finger to compress half the volume of the rehabilitation ball for 15 seconds, then relaxing for 30 seconds. This constitutes one set, with five sets forming one cycle. The above exercise is repeated four times within 8 hours post-operation with 2-hour intervals between each session. To ensure the exercises are performed correctly and effectively, audio recordings with the instructions "squeeze, relax, squeeze..." are repeatedly played for guidance.

2.3. Evaluation Methods

1) Hemodynamic Monitoring of the Operated Limb: A portable nailfold microcirculation detector was used to monitor changes in peripheral blood flow in the nailfold of the index finger on the operated side at various time points: before coronary intervention, upon returning to the ward after coronary intervention, and at 2 h, 4 h, 6 h, and 8 h post-coronary intervention. This study used a portable nailfold microcirculation detector to dynamically monitor the microcirculation on the radial side of the nailfold of the index finger on the operated side. The device is based on Laser Speckle Contrast Imaging (LSCI) technology, allowing for real-time, non-invasive capture of red blood cell movement and quantification of capillary blood flow velocity. The specific procedure is as follows: Room temperature is maintained at (23 ± 1) ˚C before measurement, with the patient resting for 15 minutes and the hand level with the heart to avoid pressure or movement. Image acquisition: The probe is fixed 5 mm from the skin surface at the first row of looped capillaries on the radial side of the left index finger's nailfold. After achieving a clear focus, a 10-second dynamic image sequence is continuously captured and repeated three times to obtain the average.

2) Swelling Degree of the Palmar Aspect of the Operated Limb: A tape measure of the same specification was used to measure the circumference of the palm and wrist before coronary intervention, upon return to the ward post-coronary intervention, and at 2, 4, 6, and 8 hours post-coronary intervention: The palm circumference was measured by looping the tape around the palm at the thumb level (cm); wrist circumference was measured with fingers straight and in line with the forearm, around the first carpal crease (cm); a specialized finger circumference ruler was used to measure the circumference of the first joint of the index finger. (To avoid errors, the initial measurement point should be marked.) Swelling value (cm) = palm circumference (wrist circumference, finger circumference) upon return to the ward, 2 h, 4 h, 6 h, 8 h, and after decompression-preoperative palm circumference (wrist circumference, finger circumference). Swelling severity classification [6]: Grade I: Skin swelling with skin creases present; Grade II: Skin swelling with non-tense blisters; Grade III:

Skin swelling, increased skin temperature, with tense blisters.

3) Pain Progression: Assessed using the Numerical Rating Scale (NRS), which consists of 11 numbers from 0 to 10, with patients using these numbers to describe the intensity of their pain, with higher numbers indicating more severe pain. 0 indicates no pain, 1 - 3 indicates mild pain (not affecting sleep), 4 - 6 indicates moderate pain, 7 - 9 indicates severe pain (preventing sleep or waking due to pain), and 10 indicates extreme pain. Patients should be asked to rate their pain and either mark or draw the number that best represents their level of pain. Pain value = pain score at 6 hours post-coronary intervention.

4) Sleep Quality Score: The Pittsburgh Sleep Quality Index (PSQI) was used to assess patients' sleep quality before coronary intervention and after decompressing the pressure device. A higher score indicates poorer sleep quality. Sleep quality value = sleep quality score after decompression − sleep quality score before coronary intervention.

5) Anxiety Score: The Self-Rating Anxiety Scale (SAS) was used to assess patient anxiety levels before coronary intervention and after decompressing the pressure device. According to the Chinese norm, the cutoff score for the SAS standard score is 50, with 50 - 59 indicating mild anxiety, 60 - 69 indicating moderate anxiety, and 70 and above indicating severe anxiety. Anxiety score = anxiety scale score after decompression − anxiety scale score before coronary intervention.

2.4. Statistical Analysis

Statistical analyses were conducted using SPSS 18.0. Measurement data are expressed as mean ± standard deviation ($\chi \pm s$) and were analyzed using the t-test. Count data are expressed as percentages (%) and analyzed using the chi-square test. A P-value of less than 0.05 was considered statistically significant.

3. Results

Changes in blood flow velocity at different surgical stages and the differences between the study group (n = 17) and the control group (n = 17).

Table 2. Comparison of changes in blood flow velocity in the operated limb after intervention between the two groups of patients (x ± s).

Group	Blood flow velocity (cm/second)						
	Pre-coronary intervention	Post-coronary intervention return to hospital ward	2 h Post-coronary intervention	4 h Post-coronary intervention	6 h Post-coronary intervention	8 h Post-coronary intervention	After Decompression
Study group (n = 17)	19.64 ± 4.31	18.82 ± 4.31	18.11 ± 3.96	18.05 ± 4.13	18.25 ± 3.80	18.47 ± 3.89	19.24 ± 4.13
Control group (n = 17)	19.82 ± 4.81	17.7 ± 4.04	17.82 ± 4.74	17.41 ± 4.58	17.21 ± 4.17	16.82 ± 4.17	17.64 ± 3.97
t-value	0.113	0.779	0.196	0.432	0.687	1.190	1.143
p-value	0.924	0.792	0.292	0.512	0.672	0.618	0.973

Baseline data showed that the preoperative blood flow velocity was similar between the two groups (study group 19.64 ± 4.31 vs. control group 19.82 ± 4.81 cm/s) with no statistical difference (p = 0.924). In the study group, postoperative blood flow velocity fluctuations were minimal, with a maximum of 19.24 ± 4.13 cm/s (at the time of releasing the compressor) and a minimum of 18.05 ± 4.13 cm/s (4 hours post-coronary intervention). The control group showed a decrease and then an increase in blood flow velocity, reaching a minimum of 16.82 ± 4.17 cm/s (8 hours post-coronary intervention), and rebounding to 17.64 ± 3.97 cm/s after releasing the compressor. The t-values at all-time points (0.113 - 1.190) did not reach the significance threshold (p = 0.292 − 0.973), indicating no statistical difference in blood flow velocity changes between the two groups. See **Table 2**.

Comparison of postoperative swelling values between the study group and the control group (n = 17/group):

Preoperative baseline: The study group's palm circumference (21.44 ± 1.73 cm), wrist circumference (17.23 ± 1.57 cm), and finger circumference (8.79 ± 1.74 cm) were slightly lower than those of the control group's palm circumference (21.97 ± 1.17 cm), wrist circumference (17.82 ± 0.93 cm), and finger circumference (9.91 ± 1.03 cm). However, statistical comparisons of baseline data were not provided.

Postoperative swelling trends: In the study group, swelling gradually increased, with palm and wrist circumferences peaking at 6 hours post-coronary intervention (22.56 ± 1.61 cm) and at the release of the compressor (18.88 ± 1.82 cm), respectively. The peak finger circumference occurred at 4 hours post-coronary intervention (9.65 ± 1.63 cm). In the control group, swelling continued to increase, with palm, wrist, and finger circumferences peaking at 8 hours post-coronary intervention (22.94 ± 1.06 cm, 19.32 ± 1.44 cm, 11.05 ± 0.81 cm, respectively).

Intergroup differences: Statistically significant differences were found in the comparison of palm, wrist, and finger circumferences at all postoperative time points (p = 0.00), with t-values ranging from 6.89 - 13.60 (palm circumference), 7.78 - 10.02 (wrist circumference), and 6.08 - 8.80 (finger circumference). Clinically, swelling values in the control group were higher than those in the study group, with the difference increasing over time. For instance, the difference in palm circumference was 0.64 cm upon returning to the ward post-coronary intervention (22.00 vs. 22.64), increasing to 0.41 cm by 8 hours post-coronary intervention (22.53 vs. 22.94).

Effect of releasing the compressor: After releasing the compressor, the swelling value in the study group showed a slight decline (e.g., palm circumference decreased from 22.53 to 22.50 cm), with a similar decline in the control group (22.94→22.82 cm), though wrist and finger circumference changes were minimal. Postoperative swelling in all areas was significantly lower in the study group than in the control group, suggesting that the intervention may effectively alleviate the progression of swelling. See **Table 3**. The study group reported lower sleep quality scores compared to the control group, a difference that was statistically significant ($P < 0.05$). Anxiety score changes were not significant ($P > 0.05$). See Table 4.

Table 3. Comparison of swelling values in the operated limb after intervention between the two groups of patients ($x \pm s$).

Group		Swelling value (cm)						
		Pre-coronary intervention	Post-coronary intervention return to hospital ward	2 h post-coronary intervention	4 h post-coronary intervention	6 h post-coronary intervention	8 h post-coronary intervention	After decompression
Study group (n = 17)	Palm circumference	21.44 ± 1.73	22.00 ± 1.53	22.26 ± 1.53	22.47 ± 1.57	22.56 ± 1.61	22.53 ± 1.62	22.50 ± 1.47
	Wrist circumference	17.23 ± 1.57	18.38 ± 1.74	18.71 ± 1.83	18.74 ± 1.80	18.85 ± 1.92	18.85 ± 1.92	18.88 ± 1.82
	Finger circumference	8.79 ± 1.74	9.41 ± 1.68	9.44 ± 1.69	9.65 ± 1.63	9.65 ± 1.63	9.62 ± 1.66	9.55 ± 1.70
Control group (n = 17)	Palm circumference	21.97 ± 1.17	22.64 ± 1.10	22.79 ± 1.02	22.82 ± 1.04	22.88 ± 1.07	22.94 ± 1.06	22.82 ± 1.15
	Wrist circumference	17.82 ± 0.93	19.11 ± 1.38	19.14 ± 1.39	19.30 ± 1.45	19.29 ± 1.45	19.32 ± 1.44	19.26 ± 1.45
	Finger circumference	9.91 ± 1.03	10.68 ± 0.95	10.79 ± 0.88	10.91 ± 0.92	11.05 ± 0.81	11.05 ± 0.81	11.00 ± 0.79
t-value	Palm circumference	-	6.89	11.83	12.99	13.60	13.56	10.03
	Wrist circumference	-	7.78	10.02	9.35	9.41	9.40	9.12
	Finger circumference	-	6.08	6.94	8.13	8.80	8.45	7.51
p-value	Palm circumference	-	0.00	0.00	0.00	0.00	0.00	0.00
	Wrist circumference	-	0.00	0.00	0.00	0.00	0.00	0.00
	Finger circumference	-	0.00	0.00	0.00	0.00	0.00	0.00

Table 4. Comparison of pain value, sleep quality value, and anxiety score after intervention between the two groups of patients ($x \pm s$).

Group	Pain value	Sleep quality score	Anxiety score
Study group (n = 17)	4.06 ± 1.14	8.62 ± 3.94	21.18 ± 2.07
Control group (n = 17)	4.29 ± 0.99	9.94 ± 3.20	20.06 ± 0.24
t-value	23.01	0.64	2.21
p-value	0.00	0.009	0.41

4. Discussion

1) Using a rehabilitation ball for exercising the operated limb does not significantly affect microcirculation in the limb, but it can enhance the nurse-patient

relationship, alleviate anxiety, improve patients' sleep quality, and increase patient satisfaction.

The fluctuation in blood flow velocity on the operated side was not significant between the two groups, with no statistical difference ($P > 0.05$), suggesting that the hemostatic pressure applied to the wrist in both groups was balanced; it was effective for hemostasis without affecting arterial blood supply to the distal part of the operated limb.

In this study, the nursing team dynamically monitored peripheral circulation (such as skin color, temperature, and capillary refill time) and adjusted pressure based on patients' complaints, which may have helped maintain microcirculation stability. However, although hemostatic pressure is considered the main factor, other potential reasons for the lack of significant effect on microcirculation should be considered. For example: Limitations of the measurement time window: Blood flow velocity monitoring focused on the early postoperative period (every 2 hours), which may not have captured later microcirculation changes. Interference from individual physiological differences: Patients' baseline vascular conditions (such as the degree of arteriosclerosis) or medication use (such as antiplatelet drugs) may partially offset the microcirculation effects of the interventions. Sensitivity limitations: Current detection methods (such as Doppler ultrasound) may lack the resolution to detect minor fluctuations in blood flow, potentially masking real differences. Future studies could further validate these findings by extending the monitoring period, incorporating vascular function stratification analysis, or adopting more sensitive technologies (such as laser speckle imaging).

There was a significant difference in sleep quality fluctuations between the two groups, with statistical significance ($P < 0.05$). In clinical practice, the presence of physical discomfort symptoms, combined with psychological barriers, severely impacts patients' sleep quality, leading to several stress reactions post-intervention. This can potentially cause arrhythmia or myocardial ischemia, which adversely affects treatment outcomes [7]. Therefore, good psychological care before and after coronary intervention helps alleviate patients' negative emotions, aids recovery, and improves sleep quality.

In a busy clinical environment, informing patients of preoperative precautions and post-coronary intervention monitoring in the ward—focusing on patient complaints, vital signs, and puncture site conditions—is essential, but psychological and emotional changes are often overlooked. By measuring peripheral microcirculation every 2 hours before and after coronary intervention, patients' psychological conditions become a focal point. Most patients experience pre-operative tension, worrying about severe vascular blockages during coronary intervention, high costs, post-operative pain, and complications. During rehabilitation ball exercises and peripheral circulation measurements, nurses can understand patients' psychological changes and provide personalized educational outreach based on these insights. This includes showing educational videos on coronary heart disease, coronary angiography, and pre- and post-operative care. Understanding the advantages of the procedure boosts patients' confidence in its outcomes, aiding recovery; alleviating anxiety improves sleep quality. Strengthened nurse-patient relationships, close attention to psychological changes, and timely and effective problem resolution enhance patient satisfaction.

2) Using a rehabilitation ball for exercising the operated limb can effectively reduce swelling and alleviate pain in the operated limb.

Clinical practice shows that prolonged hemostatic pressure during coronary intervention often results in postoperative symptoms such as hand swelling, pain, and numbness. This mainly occurs because compression at the radial artery puncture site affects venous return in the distal limb, leading to increased intravascular hydrostatic pressure and resulting in edema [8]. Additionally, compression of the wrist and subsequent edema further pressurize the median and radial nerves, causing pain and numbness in the palm and fingers [9].

In the study group, due to the use of rehabilitation ball exercises postoperatively, pain scores in the wrist and palm area of the operated limb, as well as the swelling values of the palm, wrist, and finger circumferences, were lower than those in the control group, with statistically significant differences ($P<0.05$). This indicates that rehabilitation ball exercises can effectively alleviate postoperative pain and reduce swelling. The potential reason is that after transradial coronary intervention, ischemia, hypoxia, increased skin tension, and water blisters occur, increasing the sensitivity of nerve tissues [10], leading to noticeable pain. Grip exercises can accelerate blood and lymphatic circulation and local metabolism, thus reducing swelling and local pressure, achieving pain relief for patients [11].

The results show that the degree of limb swelling in the study group was significantly less than that in the control group ($P < 0.05$), suggesting that rehabilitation ball exercises can effectively improve limb swelling and promote recovery. This is because rehabilitation ball exercises expand endothelium-dependent vessels, increasing blood flow in the forearm and the concentration of endothelial cells and vascular endothelial growth factor in the blood [12], reducing the degree of limb swelling. It also alters vascular shear stress, allowing the protective effects on vessels and tissues to be fully exerted, promoting recovery.

3) Using a rehabilitation ball for exercising the operated limb has no significant effect on preoperative and postoperative anxiety scores in patients.

There were no significant fluctuations in anxiety scores before and after coronary intervention between the two groups, with no statistical difference ($P > 0.05$), indicating that rehabilitation ball exercises do not increase psychological burden or anxiety in patients. This suggests that patients are receptive to guided rehabilitation ball exercises [13].

The results of this study showed no statistically significant difference in the fluctuation of anxiety scores before and after coronary intervention between the two groups of patients ($P > 0.05$). This finding has implications in two areas:

Feasibility of rehabilitation ball exercises: It indicates that engaging in rehabilitation ball exercises after coronary intervention does not increase psychological burden or induce anxiety, and patients have a high level of acceptance for this new rehabilitation approach.

Rationality of clinical intervention design: It suggests that under standardized guidance, rehabilitation ball training may balance negative emotions caused by postoperative activity limitations and changes in physical function through a "movement-psychological" regulation mechanism.

From a clinical perspective, maintaining stability in anxiety levels is an important goal in the postoperative management of coronary heart disease patients. Rehabilitation ball exercises, without increasing the psychological burden on patients, can be used as a complementary method to traditional cardiac rehabilitation. Especially in resource-limited settings, its characteristics of requiring no complex equipment and allowing easy involvement by family members may increase patients' adherence to long-term rehabilitation. Patients demonstrate high acceptance of guided rehabilitation ball exercises [13].

5. Conclusion

Using a rehabilitation ball for wrist exercises in patients after transradial coronary intervention can effectively reduce swelling in the operated limb, alleviate pain, ease anxiety, promote recovery, further enhance the nurse-patient relationship, and increase patient satisfaction. The limitation of this study is the lack of pressure indication on the rehabilitation ball. Determining the optimal squeezing pressure for improving swelling and alleviating pain in the operated limb remains a direction for future research.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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